inter.noise
27-30 AUGUST
HONG KONG 2017

Effects of Human Factors on the Interaction between Visual Scene and Noise Annoyance

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ABSTRACT

The relationship between sound exposure and noise annoyance has been investigated in-depth in recent decades, yet the influence of visual factors on auditory perception is not completely understood. Given a fixed sound environment, differences in perception could be caused by two major modifiers: differences in visual features and/or differences in human factors. Noise sensitivity, as one of the most representative human factors, has been investigated in many soundscape studies. Nevertheless, within audiovisual studies, human factors that more precisely address the auditory or visual dominance should be included to explain the variation among participants. In the present study, 16 audiovisual scenarios, created from the combination of 4 window-sight sceneries and 4 indoor highway traffic noise recordings, were presented to participants in a mockup living room environment. It is found that sound source visibility plays a key role in terms of visual features, whereas the audiovisual attention focusing capability of participants, i.e. the auditory acuity and the capability of participants to cope with visual distraction, affects noise annoyance, as does noise sensitivity. In addition, it is shown that the influence of visual scene on annoyance interacts with the personal factor indicating visual or auditory dominance.

Keywords: Sound, Insulation, Transmission
Section: T14.1: Soundscape in Architecture, Urban Design, and Landscape

1. Introduction

Since about 70% of the world's population will be living in cities by 2050 [1], it's an unavoidable challenge to deal with noise. The influence of sound exposure on annoyance has been thoroughly explored, especially with traffic noise in and around dwellings [2][3]. In earlier studies non-acoustic factors, such as landscape, social and behavioral factors are found to be important modifiers for sound perception [4]. Audio-visual interaction, which is at present increasingly being investigated, encompasses three major aspects: sound features, visual features and human factors. An earlier study has shown the effect of a view on vegetation on reducing noise annoyance [5]. Epidemiological research has furthermore shown that personal factors modify the influence of sound exposure on annoyance (such as age, gender, education and noise sensitivity, as well as social variables [6]). In particular, subjective noise sensitivity was shown to be a very stable personality trait which is determined both by inheritance and experience [7][8].

However, there is still a gap in understanding the mechanisms underlying audiovisual interaction and in particular, the role of human factors on the interaction. This paper focuses on the effect of human factors on audiovisual interaction in an at home situation, with the combination of two experiments: a living room experiment and an audiovisual aptitude experiment. The first experiment explored the effect of the window view on self-reported noise annoyance in a mockup living room, with a design that (i) is realistic instead of evoking a hypothetical situation through verbal description, (ii) hides the real purpose and (iii) is based on a sufficiently long exposure time. The second experiment aimed at investigating whether people could distinguish the small changes in a relatively rich sonic environment with and without (in)congruent visual information, which is expected to reveal the audiovisual aptitude of the person. Moreover, at the end of the complete experiment, after four days, a more elaborate questionnaire survey is presented to all participants to collect some personal questionnaire [9]).

2. Methodology

2.1 Living room experiment

In the first experiment, participants were asked to engage in some light activities for 10 minutes in a mock-up living room (Figure 1), during which they heard traffic sound and a window-sight scene was played on a 60-inch television. After 10 minutes a standard noise annoyance question [10] referring to the past 10 minutes with 11-point answering scale is presented. This procedure was repeated with 4 sound conditions roughly corresponding to 4 different window sound insulation situations, meanwhile the television kept playing the same visual scene. The following 3 days the exact same experiment (same procedure with same sound environments, with the sound environments randomly presented) was repeated but participants were led to believe that they simply evaluated 4 more window glazing and insulation cases each day. Yet what changed in fact was the video that was played in the background to simulate the window (Table 1). More details on this experiment can be found in [11].

Figure 1 – The mock up living room with hidden environmental noise loudspeakers indicated next to the mock-up window.

Table 1 – Four window-sight scenes (sorted by two features).

	Green elements	Non-green elements
Sound source visible		
Sound source invisible		

The four videos this experiment used contained a mixture of different natural and man-made landscape elements. Four screenshots of the video's (all taken near the city of Ghent, Belgium) are shown in Table 1. Scene (a) provides an open view of highway traffic and contains very few green elements; (b) allows vision on some parts of the highway through the woods; (c) contains a totally green visual setting; and (d) shows a series of rather traditional Belgian dwellings, along a tranquil street but presumably hiding a highway from sight. The content of four window-views can be sorted based on two features: the visibility of sound source and the presence of green elements (table 1). The sound source was completely visible in scenery (a) and partly visible in scenery (b), while in (c) and (d) no sound source was visible. On the other hand, scenery (b) and (c) contained dominantly natural elements, whereas scenery (a) and (d) contained mostly man-made elements.

The original traffic sound was recorded simultaneously with the video recording of scene (a) with a B-field microphone, which roughly represented a sound environment situation in living room with the window open. Through literature review [12], three transmission curves were selected to represent three different types of glazed windows. The recordings where filtered to simulate these transmissions. By fixing the playback software and facilities, the overall exposure sound level of these sound fragments (in the center of the room) were further tuned to 60dB(A), 55dB(A), 50dB(A) and 45dB(A), respectively.

In this 4-day experiment, not only the order of four scenes played through the four days, but also the order of four sound fragments played each day were randomized for each participant. No information on the changed window views was communicated to the participants. This setting (i) ensured a minimum impact of the presenting order, (ii) reduced the memory effect of the sound environment of the day before and (iii) helped hide the true purpose of the experiment. With this experimental design, the aim was on one hand to go beyond loudness evaluation without evoking a hypothetical situation at home with a short sound fragment, and on the other hand to hide the true purpose that is evaluation of the audio-visual interaction.

2.2 Audiovisual aptitude experiment

The second experiment was conducted at the end of the 4th day of the first experiment, and is an extension of a psychological experiment showing audio-visual interaction in attention mechanisms, to an ecologically valid, complex environmental situation. This experiment consisted of two parts. In Part 1, participants are asked to point at the sonic environment that differs from the others in a comparison between three auditory scenes, each played for 30 seconds or 1 minute. This is repeated for four scenarios. In Part 2, the same sonic environments were repeated once again but this time with visual information. However, the change in the visual scene is incongruent with the change in the auditory scene. In both parts, participants were asked the same question for each scenario: ‘Which of the three items sounds most different from the other two?’ Results collecting was straightforward in Part 1, however, in Part 2, choosing a visual different item instead of an auditory different one was marked as a visual mistake.

The outcome of this experiment allows to identify different aptitudes. It sorts out the careful listeners with good auditory memory that are able to detect even the smallest change; it allows to identify the group that does quite well on the auditory task on itself, but gets misled by the visual information; it allows to identify the group that gets completely confused by the combination of incongruent visual and auditory information, that is they think the sound is there when they hear it and/or when they see the source.

3. Results

3.1 General information

To be withheld, participants had to fulfill two conditions – having a good hearing (based on a pure tone audiometric test performed), and completing the full experiment. In the end, the experiment was performed with 69 participants. Basic demographic information is listed in Table 2.

Table 2 – Basic information of 69 participants.

Factors	Categories	Number	Percentage/%
Gender	Female	28	40.6
	Male	41	59.4
Age*	Junior(20~27yrs)	37	53.6
	Senior(28~46yrs)	32	46.4
Education	Below M.S	20	29
	Above M.S	49	71

*The age of participants varies from 20 to 46 yr, with an average of 27.9 yr and a median of 27 yr.

3.2 The interaction between visual scene and noise annoyance

A logistic regression on the possibility of being at least highly annoyed (>7) was performed for each window view (Fig. 2). At low level, even though all four lines are rather close to each other, still scene (a), which has a totally open view to the traffic and limited green elements, is slightly higher than the rest. With increasing sound level, the difference between visuals becomes bigger. At high sound level, the four lines tend to separate into two groups: sound source visible and sound source invisible groups (Table 1).

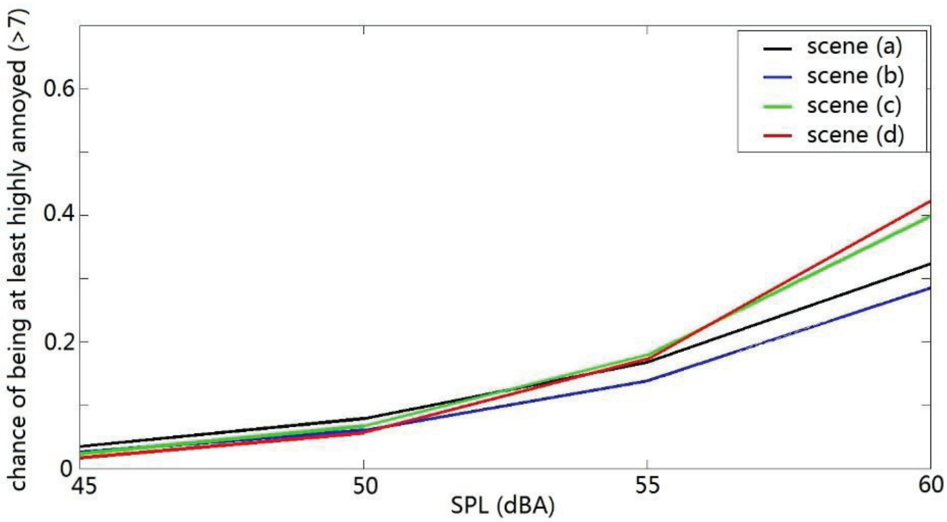

Figure 2 – Logistic regression on chance of being at least highly annoyed (>7).

3.3 Human factors

Figure 3 shows the participants distribution percentage in the second experiment (the percentages in panels (a) and (b) are the same). The x-axis represents the mistakes in Part 1, varying from 0 to 4. The y-axis represents the visual mistakes in Part 2, as described in Section 2.2, which also varies from 0 to 4. Based on whether participants could distinguish the auditory difference in all scenarios, Fig. 3(a) sorts participants into two groups – auditory acuity (dash line) and not auditory acuity (solid line). On the other hand, for participants who could do well in Part 1 but made visual mistake(s) in Part 2, Fig. 3(b) sort them out as – vision dominated (dash line) and not vision dominated (solid line).

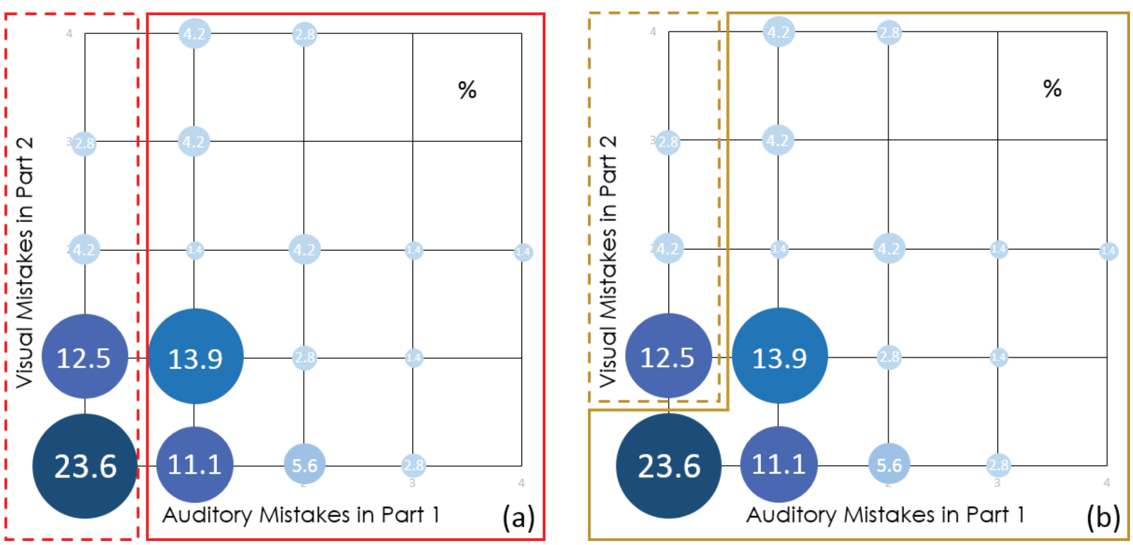

Figure 3 – Two ways of representing audiovisual aptitude: (a) Auditory acuity (b) Vision dominated.

To ensure a relatively independence between each human factor, a Pearson correlation calculation was applied to 6 human factors taken into account in this experiment. As Table 3 shows, age and education level, auditory acuity and vision dominated are two pairs of factors that are significant correlated at 0.01 level.

Table 3 – Pearson Correlations.

	Gender	Education	Age	Sensitivity	Auditory acuity	Vision dominated
Gender	1	,138	-,058	-,010	-,010	-,172
Education	,138	1	,338**	,044	,109	,144
Age	-,058	,338**	1	,120	-,054	,072
Sensitivity	-,010	,044	,120	1	,017	-,072
Auditory acuity	-,010	,109	-,054	,017	1	,549**
Vision dominated	-,172	,144	,072	-,072	,549**	1

**. Correlation is significant at the 0.01 level (2-tailed).

3.4 The impact of human factors on audiovisual interaction

A generalized linear model for annoyance was constructed, which includes the human factors (Table 3), visual features (Table 1) and their interactions. As can be seen in Table 4, sensitivity, vision dominated and SPL have a statistically significant influence on annoyance. On the other hand, two features describing the visual information – visibility of green elements and sound source – do not have a significant influence on annoyance in this model nor in a model without interactions (not shown). The interactions between two significant human factors (sensitivity and vision dominated) and two visual factors are statistical significant.

Table 4 – Generalized linear model.

Fixed Effects	Target: Annoyance			
Source	F	df1	df2	Sig.
Intercept	50.283	15	1.087	.000
Gender	2.438	1	1.087	.119
Education level	0.925	1	1.087	.336
Age	2.866	1	1.087	.091
Sensitivity	5.960	1	1.087	.015
Auditory acuity	0.020	1	1.087	.888
Visual dominated	4.129	1	1.087	.042
SPL	236.894	3	1.087	.000
Green	2.254	1	1.087	.134
Sound source	0.352	1	1.087	.553
Sensitivity*Green	1.610	1	1.087	.205
Sensitivity*Sound source	5.941	1	1.087	.015
Vision dominated *Green	4.894	1	1.087	.027
Vision dominated *Sound source	0.098	1	1.087	.754

*'Participant' is used as random factor.

4. Discussion

Fig. 2 shows the strong dominating effect of sound exposure (labelled SPL but interpreted as an ordinal variable as also the spectrum changes) on the reported noise annoyance and the statistically not significant effect of the view from the window on annoyance in the mock-up living room. At low level, the lines are rather close, scene (a) is slightly higher than the rest. On the other hand, at high level, the lines tend to separate into two groups: sound source visible group (scene (a) and (b)) and sound source invisible group (scene (c) and (d)). The other visual feature, visible green elements, does not have a significant impact on annoyance. Nevertheless, it still can be observed in this figure that, at each sound source visibility group, the scene containing green elements generates less annoyance than the other one (scene (c) is lower than scene (d), scene (b) is lower than scene (a)). This result first, confirms the impact of visual scene on reported noise annoyance. Second, it indicates that sound source visibility is more important than visible green elements in this situation. Detailed analysis can be found in [13].

In Table 3, the correlated first pair – age and education level – is logical since a senior individual is more likely to get higher education. As for the second pair, although auditory acuity is only considered in Part 1 of the audiovisual aptitude experiment whereas vision dominated is considered both in Part 1 and Part 2, there is a clear overlap between both factors (as also can be observed from Fig. 3). Nevertheless, these two factors express different aspects of audiovisual aptitude. Auditory acuity describes individual's ability of perceiving the sound precisely while vision dominated subtly sorts out those who are distracted by incongruent visual information. Individually, they both show statistically significance, but when involving more factors and interactions, only vision dominated remains statistically significant (Table 4).

As for the interactions in Table 4, it seems noise sensitivity interacts with sound source visibility and vision dominated interacts with visible green elements. The first significant interaction shows that the effect of source visibility on noise annoyance is different for sound sensitive people and sound insensitive people. For the former, source visibility tends to decrease annoyance (scilicet visible sound source scenes make noise sensitive people less annoyed). As for the latter, the trend is totally opposite. The interaction between being vision dominated and green elements visibility shows that the annoyance rating by vision dominated people is more strongly affected by the visibility of green elements, but green elements seem to increase the annoyance for this group. This could be due to a difference in expectations since vision dominated people were defined by incongruent audio and visual information. Vision dominated people have good auditory capability, which might have more strict requirements for the congruence of visual and audio information.

5. CONCLUSION

This paper focused on the effect of human factors on audiovisual interaction in an at home situation. It first confirms the impact of visual settings on reported noise annoyance. Second, it explores audiovisual aptitude, a human factor that is almost as significant as noise sensitivity, a known stable personal factor. Furthermore, the interactions between human factors and visual factors point out that visual features may not have statistical significance individually, due to the strong impact of the sound pressure level. But people with different personality will act dramatically different with the visual settings. At least this suggests that when urban acoustic design and planning is performed, human factors should be considered. Hiding sound sources or adding natural green to the environment might not reduce annoyance for everybody.

ACKNOWLEDGEMENTS

Kang Sun is funded by the Chinese Scholarship Council (CSC), the support of this organization is gratefully acknowledged.

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